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14. ABSTRACT
The Bassett Army Community Hospital (BACH) is located in the interior of Alaska on Fort Wainwright just outside the city of Fairbanks. BACH is the northernmost military hospital in the United States and the BACH staff contends with several location specific issues. These issues include "cartel-styled" pricing practiced by doctors in the civilian sector, the extremes of an Arctic climate, and the high costs associated with re-supplying a remote hospital. The facility was built in 1952 and there have been limited major upgrades and renovations to the building since that time. Several minor renovations of the "band-aid" variety have occurred. These projects were designed as temporary fixes only. A new facility is currently planned to begin in 2000. A survey of the hospital's challenges revealed several departments struggling with the legacy and future. Many departments have operational issues but questions arise concerning the level of effort to be applied when ground will be broken on a new facility in a few years. The majority of renovation efforts have revolved around inpatient wards and operating rooms. Officers working in the ancillary services revealed staffing and physical layout problems which could be addressed with simulation.

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Function and Decision - The Modeling of Selected Ancillary Activities in a Medium Sized Hospital

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Graduate Management Project

Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements

For the Degree

Of

Master of Health Administration

Function and Decision - Modeling Ancillary Activities in a Medium Sized Hospital

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Introduction

Simulation is a valuable tool for planners in both the industrial and the service sectors. Simulation first gained acceptance among industrial planners. Manufacturing plant managers and warehouse designers gained insights into facility operations and processes from realistic simulations. Many industrial operations are predictable and regular. Operations in the service sector are not so constant and modeling of these processes has proven more challenging. Many service industry planners are now using the advantages of simulation to improve operations and the bottom line. Simulation is even finding a niche in the health care arena. The rise of fiscal pressures on health care organizations is partly responsible for the trend toward using simulation to identify internal operational weaknesses and improve efficiencies. Entities like health maintenance organizations have led the way in developing information systems which can profile physician practices, link organizations, and handle digitized data from new imaging systems. More and more variables are thrown into the health care arena each month. Administrators are continuously searching for new ways to plan services and manage operations. Simulation is a tool which offers viable solutions for these questions with limited impact on budgets.

Though simulation in the service industry differs somewhat from the industrial area (service industry simulation usually requires intensive data gathering over larger periods of time when compared to industrial operations) the payoffs are similar.

Simulation offers a tool to managers which allows a "God's eye" view of their operations. Managers can analyze that environment via simulation, measure the results, and test theories which could otherwise consume extensive resources and time. Simulation also allows the testing of new ideas dealing with operations without unnecessary impact on customer relations.

A good simulation requires the involvement of staff members at all levels of the organization. Development of a simulation is a good opportunity to build organizational cohesion and solicit input from varying members of the staff. Staff members who contribute to the simulation process and actually experience changes which are implemented because of the project develop genuine feelings of contribution; "…Simulation can promote communications by allowing everyone involved to see the results of their assumptions and the impact of their decisions on the work of others…" (Bateman, Bowden, Gogg, Harrell, and Mott p.11)

The ProModel Corporation of Orem, Utah was founded by Charles Harrell in 1978. ProModel began by providing computer simulation support to the industrial sector but has since branched out into the service arena. *MedModel* is a Windows based simulation software package developed by ProModel specifically for health care organizations. *MedModel* has had positive impacts on health care operations all over the United States and is the simulation program chosen for this project.

Conditions which Prompted the Study

The Bassett Army Community Hospital (BACH) is located in the interior of Alaska on Fort Wainwright just outside the city of Fairbanks. The facility was built in 1952 and there have been limited major upgrades and renovations to the building since that time. Several minor renovations of the "band-aid" variety have occurred. These projects were designed as temporary fixes only. A new facility is currently planned and construction is scheduled to begin in 2000. BACH is the northernmost military hospital in the United States and the BACH staff contend with several location specific issues. These issues include "cartel-styled" pricing practiced by doctors in the civilian sector, the extremes of an Arctic climate, and the high costs associated with re-supplying a remote hospital.

A survey of hospital challenges revealed several departments struggling with this legacy and future. Many departments have operational issues but questions arise concerning the level of effort to be applied since ground will be broken on a new facility in a few years. The majority of renovation efforts have revolved around inpatient wards and operating rooms. Officers working in the ancillary services revealed staffing and physical layout problems which could be addressed with simulation.

The BACH **pharmacy** department faces several physical layout and operational changes in the near future. These changes include removal of the rolling storage shelves, redistribution of administrative work stations, and replacement of the Baker

cells with "cassette" cells. (These changes were prompted by fiscal constraints and work flow concerns). Simultaneously, the pharmacy leadership desires to improve patient privacy. Currently patients are counseled at the window in full view of other patients and staff. The pharmacy leadership would like to improve patient privacy while maintaining the current number of pharmacy workers. This will require a physical layout and staffing setup which improves on earlier configurations and incorporates the coming changes in the pharmacy department.

The BACH **laboratory** officer believes the lab can function more efficiently. She suspects a rearrangement of testing equipment will facilitate quicker turn around times for procedures. The lab officer suspects the planned new facility will provide these changes. She also believes this may be accomplished with a reduction in personnel.

Bassett Army Community Hospital is currently facing a large decrement in personnel. This decrement includes several physicians one of which is a radiologist. The final decisions concerning these decrements has, as of now (April 99), not been made. The BACH **radiology** section currently utilizes the services of two full time military radiologists. The loss of one radiologist would severely impact the section. The leadership of BACH and the BACH radiology section wish to understand the quantifiable impact the loss of one radiologist would have on the section.

Problem Statement

This study seeks to answer several questions, through the use of simulation software, concerning the Bassett Army Community Hospital (BACH) ancillary services.

1) Can simulation software help choose the best of three proposed designs for the BACH pharmacy?

2) Can the use of simulation software improve the operations of the Bassett Army Community Hospital (BACH) laboratory by optimizing the physical layout?

3) Can the use of simulation software quantify the impact of losing one radiologist at the BACH?

Literature Review

"...Decisions, concerning the admission, treatment or discharge of patients, are based mainly on medical criteria, but at the same time the allocation of resources within the hospital is made by administrators. It is the totality of these decisions, both medical and administrative, which determines how efficiently the hospital is run." (Blewett, Grove, Massinas, Norman, and Southern p.139)

A review of the literature encompassed sources outside of health care to include the operational sciences and industrial engineering. The earliest paper on simulation and modeling in health care found was Fetter and Thompson's 1965 study. Fetter and Thompson used a program written in SIMSCRIPT to model a maternity suite, an outpatient clinic, and a surgical pavilion. Benneyan (1997 p.3) notes that Roberts and English (1981) report

the use of simulation as early as 1962 in the study of emergency and non-emergency admissions. For many years simulations were written in computer languages like FORTRAN, BASIC, and C+ and outputs were in the form of numerical charts. These simulations sought to represent relationships between key elements of a system solely with equations. Studies in 1972 used FORTRAN programs to determine minimum staffing requirements (Johnson, Myers, and Egan et al) and variables that effect patient waiting times (Brook, Feiglin, and Brooks). A study by Blewett, Grove, Massinas, Norman, and Southern in 1972 attempted to harmonize the operations of two ENT physicians with two ophthalmology physicians. The modelers, using FORTRAN IV, constructed separate models for each situation to test their hypotheses. In 1977 mathematical modeling techniques were used in strategic "game" scenarios to find relationships between health care decisions on the strategic level and the health of a population (Clayden). Simulation in health care had caught-on in the 1960's and 70's and a library of literature started to form;

> "…Shuman and Wolfe (1992) note that by 1975 over two hundred simulation healthcare studies had been reported in the literature, and in 1981 Roberts and English (1981) published a bibliography of 427 journal and conference citations." (Benneyan p.3).

The literature reveals a tendency for most authors to "introduce" simulation and "walk" readers through the simulation process. Many papers have the same six or seven step process from *defining the problem* to *implementation*. This suggests that

even as simulation makes great contributions to many organizations an equal number of institutions ignore simulation and retard its growth.

A model is a "...simplified representation of the real world..." (Dean, Gallivan, Barber, and Ackere p.2492). A realistic model allows the modeler to investigate alternate forms of established processes without "...experimenting with operational changes in the clinic which can be disruptive, time-consuming, costly, and difficult to monitor..." (Hashimoto and Bell p.184). Early models could be as simple as a two dimensional map but the modern modeler uses high speed computers, distribution fitting statistics software, and eye catching animation to simulate health care systems. The mathematical models of the 1960's and 70's which required specialized knowledge and advanced programming ability gave way in the 80's and 90's to sophisticated software packages that allow any manager or planner to become personally involved with simulation projects and to constructively follow their progress.

A simulation represents a system which is composed of separate processes. One of the modeler's challenges is to break the system down into discrete processes to a level of detail which answers the proposed questions. A good simulation manipulates inputs to the system in a way which mirrors reality. A simulation which has inputs that are fixed and unchanging is called *deterministic.* When the inputs display variability or randomness the simulation is labeled *stochastic.* Simulation software "fits" observed data to mathematical distributions and

"generates" random numbers from these distributions to mimic specific variabilities.

Simulation promises advantages for organizations but many models fail to live up to expectations. Keller, Harrell, and Leavy (1991) cite three main reasons why simulations fail: 1) failure to properly "sell" simulation to staff and management 2) lack of education on the modeler's part concerning the simulation software or the system under study and 3) unrealistic time expectations. Others see the main challenge to simulation differently;

> "The main disadvantages of modeling are that the validity of the model as a representation of the real world can be difficult to ascertain and that users must be convinced of the validity of the model before its conclusions can be put into practice." (Dean et at p.2492)

At some future time simulation may be as accepted in health care as catheters and tongue depressors. Until that time the ambassadors of simulation will be the modelers themselves. Its acceptance will depend on their successes.

Fetter and Thompson (1965) searched for the answers to familiar sounding questions; what are the best policies to govern the scheduling of surgical suites?, how can patient waiting times be reduced in the outpatient clinic?. A survey of health care simulation literature supports the idea that few problems are ever solved eternally; we must continually develop new solutions which address recurring problems. Simulation gives us the capability to face these problems and even allows

us to foresee problems before they arise.

Purpose

The objective of this study is to analyze current ancillary service operations at Bassett Army Community Hospital by developing accurate simulations using MedModel3 software. The services to be modeled are the laboratory, pharmacy, and radiology departments:

1) The goal of the pharmacy simulation is to establish a physical layout and operational flow which facilitates improved patient privacy and lower patient wait times without increasing current pharmacy staffing levels. This should be accomplished while maintaining current levels of throughput statistics. (Throughput statistics include total number of patients served). Pharmaceutical orders will be broken down into the following types 1) orders from "non BACH" physicians and 2) orders from "BACH" physicians.

2) The goal of the laboratory simulation is to improve services by determining the most efficient space management configuration in the new Bassett Army Community Hospital (NBACH). Success will be measured by a minimum 3% reduction in turn around times for lab processing.

3) The goal of the radiology department simulation is to quantify the impact of losing one radiologist. Radiology operations will be modeled in the NBACH facility. Simulations with two and one radiologist will be compared, specifically in relation to their impact on total times patients spend in the

clinic.

Methods and Procedures

A successful modeling project involves several key steps. The first step in a modeling project is **definition of the problem**. The problem should be specific in scope and developed with involvement from the section staff. The problem definition will drive all requirements for the model including the level of detail in the simulation. Simulations need only model those processes and activities which are required to answer the problem; "...keeping things simple makes modeling easier and far more productive and generally doesn't sacrifice one bit of validity!" (Lange p.32). The three problem statements in this study were developed after meetings with department staff.

Model formulation is the next step and begins with dissection of the system under study into separate processes. A process chart can help during this step. Several elements from the system must be identified. These elements include 1) entities - those persons or things which move through the system 2) resources - persons or things which perform tasks on entities 3) locations - places where tasks and events occur and 4) path networks - routes on which entities and resources travel. Schedules, downtimes, arrival rates, and other details pertinent to the study are elements which must be included in the model.

Several areas of the process will require data from the observed system. An example is patient arrival rates. Once adequate **data** is gathered concerning patient arrivals the data

is displayed on a histogram. The number of interval bins for the histogram may be determined using Sturge's Rule = $|1+3.322\log n|$ (n=sample size). The empirical data is then "fitted" to a theoretical distribution. The "goodness of fit" can be tested with a Chi-square test. Several commercially available software packages can perform Chi-square tests on empirical data and theoretical distributions. Data can also be used more directly in the form of **arrival tables**. Arrival tables list values for arrivals over specific periods of time. Usually arrival tables list the number of arrivals per hour in a sequential format throughout the day. Arrival tables more accurately mirror data and can model "highs" and "lows" over the course of the workday. Theoretical distributions can be used in conjunction with arrival tables to generate stochastic results.

The completed model fits all the elements in the formulation process together into a functioning model. MedModel3 accomplishes this using animation with Windows based format. Animation is a valuable tool which helps establish face validity. As with all steps in the modeling process staff members should figure prominently. The model will have little validity among organization members without the approval of staff members.

The next step is **verification** and **validation** of the model. **Verification** refers to the simulation performing the way it was intended to perform. Slowed down animation allows staff to carefully view the action of the model on screen and verify its processes. **Validation** can be accomplished several different

ways. Data generated by the model can be compared to the data gathered during the model building process. An independent t test is then used to test for significant differences in the data. Another process of validation, called the Turing process, includes presenting staff members or other "experts" several sets of data, some gathered through observation and others generated by the model. The "experts" then attempt to find discrepancies between the data. Any problems found should propel the modelers to "debug" and improve the simulation.

Experimentation is the heart of the simulation process. The objectives of the study are directly addressed in the experimentation stage. The modelers, in concert with staff members, change aspects of the model such as number of resources, schedules, physical layout, etc. to solve the problem under study. The modelers must determine values for factors which may affect the outcome of the simulation to include "warm-up" time for the simulation and the correct number of replications to achieve an accurate outcome.

Careful records should be kept which track the progress of experimentation. A thorough **results analysis** will document all alternative processes and show the tests used to determine significance. The modeler must keep in mind that any results must include realistic assessments of implementation potential, including financial impacts.

Implementation is the final stage of a simulation project. Implementation does not always mean adoption of new operations. It refers to adoption of conclusions derived from the project;

many simulations result in cancellation of planned changes due to a surprising results analysis. The true test of success of any simulation project is acceptance of conclusions. This requires not only a realistic simulation of operations, good data gathering, and thorough experimentation but establishment of validity and reliability among the leadership of the organization.

The Pharmacy

The pharmacy project was approached as a group project. The project incorporated the input of all the members of the pharmacy staff. The pharmacy leadership held regular meetings to solicit staff input. Though, the project tried to answer the general question, "What is the best layout?" several smaller questions inevitably rose out of discussions. These questions included the following; 1) how best to use the area formally occupied by the space saver shelves? 2) can a patient counseling area be incorporated into the new design? 3) can a new design help with controlling patients waiting on prescriptions? 4) how will a new design affect patient wait times? Only one of these questions (#4) can be answered quantitatively through modeling but the other questions are indicative of the issues raised by including entire staffs in a redesign project. The modeling process proved helpful in reaching conclusions on these issues.

The actual modeling process was begun by constructing an accurate layout of the current pharmacy design. Detailed blueprints were obtained from facility engineers to aid in this process. Interviews were conducted with the pharmacy staff so

the modeler could clearly understand pharmacy operations. The operations of the pharmacy were broken down into five general areas: 1) **Outpatient pharmacy** - central activity hub where 2-3 staff members interact with patients throughout the day and fill drug orders. 2) **Inpatient pharmacy** - one staff member receives drug orders via fax and delivers orders to wards. 3) **Supply area** - one staff member receives daily supply shipment, breaks down shipment, and delivers supplies to all pharmacy areas. 4) **Counseling** - office styled area where one pharmacist counsels patients concerning their prescription. 5) **Administrative** - office area for the pharmacy staff (The pharmacy currently maintains administrative space (three offices) outside of the main pharmacy area but will lose two of these offices to the Veteran's Administration in the spring of 1999).

The current pharmacy design includes a "large", centrally located outpatient pharmacy area. This area encompasses approximately one half of the total square footage in the pharmacy. The inpatient pharmacy and the supply sections are located on either side of the outpatient pharmacy and the space saver shelf area is adjacent to the supply area. The space saver shelf area was being dismantled while the pharmacy modeling project was underway. The removal of the space saver shelving freed up close to 30 square feet of usable space. The availability of this space is what initiated the drive to establish a new design for the pharmacy.

New designs attempted to establish a "best" design by manipulating the three main pharmacy sections (inpatient,

outpatient, and supply) and accommodating a counseling area and more administrative space. Modeling allowed pharmacy staff to promptly evaluate their ideas in a qualitative manner.

Data was gathered to determine the current rate at which patients arrive in the pharmacy and to determine the length of time to complete the tasks involved in filling a pharmacy order. Arrival rates were determined using the composite healthcare system (CHCS) which captures data on patients. Data was combined for all weeks in October to construct one average representative day. Appendix I displays the arrival rate data for the BACH pharmacy for October 1998 and the resultant averages for each hour of each day of the week. Patients who arrive in person to pick up orders are of two types - 1) **BACH patients** - those patients who receive prescriptions within BACH and then move to the pharmacy to receive their prescriptions and 2) **"downtown" patients** - patients who bring in prescriptions written outside of BACH to be filled by the BACH pharmacy. The orders from each of these patients under go similar but different sets of processes. These figures were used to build "arrival tables" which reflect the work load of the BACH pharmacy. A triangular distribution was chosen to model the arrivals within each separate hour. The triangular distribution utilizes the **minimum, maximum, and mode** of a given sample of values. The arrival table approach enables the modeler to replicate operations which closely mirror the gathered data.

A model of the current design, though never an option for the future, was completed in an attempt to quantify the

improvements of new designs and establish validity for the model. Three options were decided upon for testing. These options were evaluated separately for their operational advantages and financial feasibility. Each proposed model included elements which the staff wished to test for efficiency. Preliminary conclusions derived from the modeling program were incorporated into a decision brief presented to the hospital commander. Modeling was used as only a piece of the overall briefing format but modeling influenced every phase of the project.

A chi squared statistic was calculated using patient exit results from the model of the current pharmacy. The table for the chi squared test is displayed in appendix VII. A comparison of expected numbers of patient exits with observed patient exit numbers does not categorically validate the model but lends support to its accuracy. Face validity was obtained by allowing the pharmacy staff to inspect the model in detail.

Five advantages/disadvantages (criteria) were chosen as measures of design suitability: 1) **Supply Workflow** is measured by the number of pharmacy work areas which must be crossed to resupply separate pharmacy sections. (The pharmacy work areas are inpatient, outpatient, counseling areas, and administrative). 2) **Waiting area management** (WAM) is measured by the percentage of patients who utilize the designated pharmacy waiting area. WAM is the most qualitative measurement of the five criteria. WAM reflects experience with BACH pharmacy patients. BACH Pharmacy patients tend to clog the

hallway by waiting directly in front of the large central outpatient window even though a television is provided for them 20 feet down the hallway in the designated waiting area. If the windows are reduced in size and moved to the far corner of the pharmacy the patients will tend to congregate around this new window area which will be in the designated waiting area. 3) **Cost to complete project** is measured by the estimated cost of each design. The facilities branch provided cost estimates after reviewing the submitted designs. 4) **Counseling areas** are measured by the number of counseling areas provided for by the design. (The smaller pickup window in option 1 is considered one counseling area. Designated space for a separate counseling area is considered one counseling area). 5) **Waiting times** are measured by the patient wait times predicted by the model. Modeling provided a direct quantitative impact only on criteria #5 but each of the other evaluation criteria (except cost of the project) were derived in a qualitative sense from time spent interacting with the model.

Each of the three options are summarized below with the pertinent changes incorporated and the pros and cons of each model:

OPTION 1 (see Figure 1)

Changes;

- Inpatient area moves to the space saver shelf area
- "In" and "Out" windows installed on right side as part of the outpatient pharmacy
- Counseling area incorporated on the far right

- Expanded supply area located between inpatient and outpatient areas

Advantages;

- Improved supply workflow
- Better waiting area management
- Accommodates counseling areas

Disadvantages;

- High cost (> $35,000)
- High patient wait times

OPTION 2 (see Figure 2)

Changes;

- Inpatient area moves to the space saver shelf area
- Administrative area on right side
- Counseling area incorporated on the far right
- Supply area located between inpatient and outpatient areas

Advantages;

- Improved supply workflow
- Low cost
- Low patient wait times

Disadvantages;

- Poor waiting area management
- Only one patient counseling area (front desk)

OPTION 3 (see Figure 3)

Changes;

- Administrative area moves into space saver shelf area

(this design is very much like the current design)

Advantages;

- Virtually no cost
- Low patient wait times

Disadvantages;

- Supply work flow is poor
- Waiting area management is poor
- Provides for no privacy to counsel patients

Current Pharmacy (see Figure 4)

Note - Large central outpatient window
- Space saver shelf area (being freed up for other uses)
- Poor positioning of the supply area
- No counseling or administrative space

Wait times for pharmacy customers at the current BACH pharmacy are relatively fast. The models indicated wait times for BACH patients ranging from 2.40 mins to 3.63 mins. This relatively minor change to an already acceptable standard for waiting caused wait times to be weighted least in the decision matrix. The pharmacy leadership considered **workflow** and **waiting area management** to be the leading considerations in the decision matrix. The team utilized the Decision Matrix format and software used at the United States Army Combined Armed Services

Staff School. Table I displays the courses of action and the evaluation criteria. Appendix II contains the completed decision matrix. **Efficiency** represents a combined total of the average wait times for the two types of patients.

TABLE I

Evaluation Criteria (Benchmark)				Courses of Action		
Work Flow		Option 1	=	Option 2	>	Option 3
<1		0		0		1
Wait area mgmnt		Option 1	>	Option 2	=	Option 3
50%		75%		25%		25%
Cost		Option 3	>	Option 2	>	Option 1
$31,300		$60,866		$19,000		$14,000
Privacy		Option 1	>	Option 2	>	Option 3
>1		2		1		0
Efficiency		Option 1	>	Option 2	=	Option 3
<7.48		8.63		7.13		6.68

Information concerning the decision matrix is included in this report to demonstrate how modeling was incorporated into a project with a diversity of decision tools.

The pharmacy staff ultimately decided to recommend option 1. Construction costs were mitigated after a phased construction program was introduced and plans to share costs with the Veteran's Administration were finalized. Construction on option 1 began in March 1999. Modifications included sharing half of the construction costs with the VA and increasing the budget for furniture. The final price of the project for BACH is $58,000. The project should be completed in the summer of 1999.

Though the increase in wait times was deemed acceptable an

analysis of wait times shows statistically significant results;

Table II

Pharmacy Results					
model	patient	avg wait time	std dev	# replications	std err of the mean
current	BACH	2.89	1.464	300	0.08452
	down town	5.349	3.132	300	0.18083
phar 1	BACH	3.631	2.66	450	0.12539
	down town	5.007	2.211	450	0.10423
phar 2	BACH	2.64	2.065	250	0.13060
	down town	4.487	1.717	250	0.10859
phar 3	BACH	2.398	1.04	350	0.05559
	down town	4.285	1.138	350	0.06083

# of replications was determined with the equation;

$$N = \frac{[(t)(s)]}{e}^{2}$$

where N = number of replications

t = critical value from the t-distribution

s = point estimate for the standard deviation

e = amount of acceptable error

A comparison of the means reveals a strong significance in favor of models 2 and 3 but does not indicate a significant difference between these two models (see Table III).

Table III

t - tests p = .05			
model	**patient**	**t**	
phar 1 /	BACH	5.4735	> 1.96
phar 2	downtown	3.4547	> 1.96
phar 1 /	BACH	8.9893	> 1.96
phar 3	downtown	5.9828	> 1.96
phar 2 /	BACH	1.7049	< 1.96
phar 3	downtown	1.6229	< 1.96

Model #1 was shown to be significantly slower than the current model for **BACH** patients and insignificantly faster for **downtown** patients. Model #2 was significantly faster only for **downtown** patients when compared to the current model and model #3 was significantly faster for both types of patients when compared to the current model. (See appendix III for comparisons of models with current pharmacy).

The four questions posed by the study were answered by the project;

1) How best to use the area formally occupied by the space saver shelves? **Use this space for the inpatient pharmacy.**

2) Can a patient counseling area be incorporated into the new design? **Yes, at the far right side.**

3) Can a new design help with controlling patients waiting on prescriptions? **Yes, experience indicates patients will wait for orders near the window - the new window will be located in the designated waiting area.**

4) How will a new design affect patient wait times? **Model #1 will probably cause patients to wait significantly longer for orders to be filled but the impact will be acceptable.**

The study could have been improved by choosing a quantifiable variable with more impact on the study. Modeling did help the decision making process at each stage of the project but in qualitative ways. The project could also have been improved by including the Veteran's Administration (VA) design and operations into the model. The VA is located on the first floor of the hospital on the same hallway as the pharmacy. Many of the issues concerning the pharmacy were shared and due in part to VA operations. The interaction of the pharmacy with the VA provided the bulk of discussion during the decision phase of the project. A model which included ideas from both areas and illustrated these points of concern would have proved helpful.

Areas for future study include the implementation of the new pharmacy operations in the designs for the NBACH. The NBACH was used as a basis for study in the models for the laboratory and radiology sections but was not used for the pharmacy since the end result concerned only the current facility.

The modeling tool proved useful to this project for two main reasons; the model lent credibility to the analysis of the

separate options and allowed the pharmacy staff to see their "ideas in motion". Though qualitative in nature the latter reason was exceptionally valuable. The end result of modeling is, hopefully, some type of quantitative measure but the idea forming phase of any project is a largely haphazard "hit and miss" operation. The models acted as catalysts for this stage and helped bring into existence the ideas which made for a better pharmacy.

Laboratory

Construction of the new Bassett Army Community Hospital (NBACH) is scheduled to begin in the spring of 2000. The NBACH design is a radical departure from the 1950's styled layout of the current BACH. In the NBACH services, clinics, and wards project radially outward from a central cylindrical tower. The laboratory will be located on the first level between patient administration and the radiology section. The laboratory modeling project sought to answer the question what is the impact of alternate arrangements of equipment for the BACH Laboratory in the new hospital (the NBACH)? The basis for alternate layouts of equipment is **function** and **process**.

The model for the laboratory project was begun by obtaining blue prints from the facility engineers for the current BACH and plans from the health facility planning cell for the NBACH. The laboratory in the current BACH is arranged linearly throughout several adjacent rooms. Three of the rooms contain all the equipment for the main processes of the lab. The main processes

of the lab are **chemistry, urinalysis,** and **hematology**. The blood bank is located at one end of the lab but is accessed by the staff only sporadically. **Microbiology (micro)** is located about 70 feet from the main lab on an adjacent hallway.

The laboratory officer was interviewed concerning the processes within the lab. Samples are obtained from patients by drawing blood in the phlebotomy area or obtaining urine samples in the latrine area. Other blood and urine samples obtained from wards and clinics throughout the hospital arrive at a receiving point. A staff member in the **computer room** receives each sample and logs it into the composite health care system (CHCS). He also "spins" a portion of the blood samples in the centrifuge. Once processed the computer room clerk places all samples in a wait cart for pickup. Staff members from the chemistry, urinalysis, and hematology sections pickup samples from the wait cart and move back to their work areas. In the work areas the staff member logs the sample into the CHCS, processes the sample in a machine, and then stores the sample. Some urinalysis and hematology samples are viewed under a microscope. A certain portion of the samples are picked up by the **micro** staff member and processed through the micro location. The micro staff member "grows" cultures of samples and views them under a microscope. The urinalysis and chemistry staff members are cross trained and can process each other's samples. Patients do not wait for their results. Patients depart the lab area as soon as they provide their sample.

The current BACH lab and the NBACH lab are similar in

several ways. The processes of receiving patients, obtaining blood and urine samples, and processing samples through a computer room choke point is the same. Though the **Micro** area will be co-located with the new lab **micro** operations are still distinct from the three main lab sections and require separate space. The main difference between the two facilities is that the NBACH has a large central area where the three main lab sections can be located. It is assumed that this alone will unlock a certain degree of efficiency not yet realized. However, the best arrangement of lab equipment remains a central question.

Two approaches to the arrangement of lab equipment are the **function** approach and the **process** approach. Practically all systems arrange equipment and personnel in a manner which reflects one of these perspectives.

A system modeled around **functions** co-locates all personnel and equipment which perform like functions. Each of the main sections of the lab (chemistry, urinalysis, and hematology) entail three main functional steps. These steps are 1) log the sample into the CHCS, 2) process the sample through the section equipment, and 3) store the sample. Figure 5 displays the laboratory arranged in a functional format in the NBACH.

A system modeled around **processes** co-locates all personnel and equipment involved in the entire process. Each of the three main lab sections can be considered a separate process. Figure 6 shows the lab arranged in a process format in the NBACH. The current laboratory configuration is a process oriented layout.

The process oriented layout for the NBACH is used in this study as a standard against which alternate configurations will be measured.

Other variations on the **function/process** arrangement includes **spatial orientation**. Figures 7 and 8 show the lab equipment arranged along **function and process** lines but with different spatial presentations.

Data was obtained through the CHCS system and daily logs of the laboratory. Ten different days of data reflecting arrival rates for patients was compiled (see appendix IV). The data was compressed by hour to "build" one representative ten hour day. A triangular distribution was chosen to model arrival rates. The expert knowledge of laboratory professionals was relied upon for data concerning other nuances of the BACH lab operations to include average processing times at each location.

Required number of replications was obtained with the replication equation (see page 23). After running ten replications the tolerated error was chosen as 5% of the resulting average for urine samples (urine samples fluctuate the most). Resulting required replication figures were between 250 and 400 for the separate models.

Three alternate models were selected to compare to the standard model, which is based on **process** (figure 6). The three alternate models are based on **function** (figure 5), **process oriented horizontally** and **function oriented vertically** (figure 7), and **process oriented vertically** and **function oriented horizontally** (figure 8). Spatial indicators are with respect to

the visual orientation of the model on paper. The NBACH blue prints show the radiology section adjacent to the lab at the "top of the page" and the patient administration section is adjacent to the lab at the "bottom of the page". To the far right is the cylindrical central tower.

Table IV displays pertinent data to include average processing times for each sample and the # of replications run for each model. The lowest total average processing time was obtained by model #1 (process - vertical, function - horizontal), the slowest total average processing time was obtained by model #2 (function). Models based on an equipment arrangement which incorporated both process and function were faster than the models based only on function or process. Coagulation sample processing times deviated the least across the four models (11.50 to 11.99). Coagulation samples have the "straightest" path to travel in the lab and the most dedicated staff member. The hematologist (who processes the coagulation samples is not cross trained for either of the other samples). Urine and serum samples processing times fluctuated significantly. Urine and serum samples can be further processed after the machine stage by moving to the scope and/or going to the micro section. Urine and serum staff members also divide their time among all three lab sections.

Table IV

Laboratory Results					
Model #	**sample**	**avg processing**	**std dev**	**# replications**	**stnd err of the mean**
1		**time**			
Pro - Ver	**urine**	33.74	17.06	300	0.98
Fun - Hor	**serum**	24.92	13.71	300	0.79
	coagulant	11.85	1.86	300	0.11
total avg pro time		**70.51**			
2					
Function	**urine**	42.17	24.95	400	1.25
	serum	33.09	21.63	400	1.08
	coagulant	11.99	1.91	400	0.10
total avg pro time		**87.25**			
3					
Pro - Hor	**urine**	34.01	18.37	325	1.02
Fun - Ver	**serum**	25.72	15.57	325	0.86
	coagulant	11.5	1.84	325	0.10
total avg pro time		**71.23**			
Current					
Process	**urine**	37.6	20.56	250	1.30
	serum	29.82	18.34	250	1.16
	coagulant	11.58	1.96	250	0.12
total avg pro time		**79**			

Independent samples design t-tests showed all the models to be significantly different for at least two of the samples (urine and serum) at the **p** =.05 level. Model two was significantly different than the standard for all three of the samples but in the negative (slower) direction. Complete t-test results are included in Appendix V. Results for Model #1 are displayed in Table V;

Table V

Lab Results t - tests p = .05						
	t - test current model / model 1					
urine	2.36	> 1.96	reject null hypothesis accept alternate			
serum	2.48	> 1.96	reject null hypothesis accept alternate			
coagulent	-1.66	< 1.96				

Model #1 arranges the lab equipment sequentially from the point where samples enter the system (far right) to where samples end up in storage and/or in the micro section (far left). Model #1 provides the clearest paths for each staff member ensuring a minimum of conflict. The dominance of the "combination" layout (function and process) suggests a certain degree of "spacing" between equipment is required to facilitate laboratory operations. Both the process and function models rely on clustering of equipment which may inhibit a needed fluidity.

The lab officer should employ a combination approach to setting up the laboratory in the NBACH. This approach should orient the processes and functions of the lab along clear axis with respect to the flow of samples. Further areas of study could include quantifying the value of cross training all three staff members to include drawing blood and logging samples into CHCS in the computer room.

Radiology

The radiology project, like the laboratory project, places current BACH radiology processes in the setting of the NBACH. The research question concerns measuring the impact of a shift in personnel resources. Presently the BACH enjoys the services of two radiologists. A decrement of one radiologist has been proposed by resource managers at the Regional Medical Command. No requisite shift in beneficiary populations is expected. This change in assets poses a significant problem for the BACH radiology staff. A model which quantifies the impact on the BACH staff may prove valuable to BACH resource planners.

The radiology project was begun much like the pharmacy and laboratory projects. A floor plan of the NBACH radiology section was obtained from health facilities and detailed interviews conducted with the radiology staff. Once the operations were understood data was gathered concerning patient arrivals and model replications run.

The BACH radiology section provides five distinct services to BACH beneficiares; mammography, CAT scan (CT), fluoroscopy, ultra-sound (US), and routine xrays. The BACH radiology section instituted the digital patient archiving system (PACS) in October 1998. This system allows BACH radiology staff to post and access digital pictures on a system shared electronically by other treatment facilities. PACS eliminates the need for most film processing. The only service which continues to use processed films is mammography.

Figure 9 shows a layout of the NBACH radiology section. The

front desk of the radiology section is located near the "center" of the NBACH circular design close to the central tower and close to where patients will first access the radiology system. The NBACH design provides for three separate waiting areas for patients; one waiting room for mammography and CT patients, one waiting room for routine and US patients, and one waiting room for fluoroscopy patients.

The processes within each of the five areas, while distinct in their own ways, are very similar from a modeling perspective. Each area accomplishes seven tasks; 1) patients arrive in a waiting area, 2) orders in the CHCS system are "matched" with waiting patients, 3) some or all of the patients change clothes in a dressing room, 4) patients move to the section room which contains the radiology equipment, 5) patients interact with the equipment with radiology staff, 6) patients wait in the equipment room while staff validate the image, and 7) patients change back into their clothes and exit the system. Fluoroscopy requires the presence of a physician for at least some of the process each time it is executed. Images are validated when the physician accesses the images on the PACS system. The mammography clerk hand carries the mammography images to the physican's offices to validate the image. The fluoroscopy and routine areas share a common cassette reader which is used to post the digital pictures of these areas on the PACS.

Data was gathered for four days on each of the five radiology sections. Data for radiology patient arrivals is listed in appendix VI. The data indicates very regular arrival

rates for patients for four of the areas; mammography, CT, fluoroscopy, and US which is reflective of the radiology appointment system. Routine xrays experience some variability and the highest patient concentrations (about 25 / day). All radiology technicians are trained in performing routine xray procedures and all are used in the model to do so when they are not required in their respective sections.

This data was averaged by hour to create one representative twelve hour day. Arrival tables were built for each hour of a typical day. A combination of triangular and normal distributions were used to model patient arrivals.

A chi squared statistic was calculated using patient exit results from model one (two physicians). The table for the chi squared test is displayed in appendix VII. A comparison of expected numbers of patient exits with observed patient exit numbers does not categorically validate the model but lends support to its accuracy. Face validity was obtained by allowing the radiology staff to inspect the model to include time to complete specific procedures within each of the five areas.

450 replications were run on two different models. Model one reflects current radiology services utilizing two physicians. Model two shows the effects of services using only one physician. The results are listed in table VI.

Table VI

Radiology Results						
model	patient	avg processing time	std dev	# replications	std err of the mean	% increase
rad 1	ct	61.434	9.352	450	0.441	
	flu	128.016	26.875	450	1.267	
	mam	73.784	25.368	450	1.196	
	rout	70.437	18.262	450	0.861	
	us	64.895	10.808	450	0.509	
rad 2	ct	84.754	15.351	450	0.724	38%
	flu	174.163	39.516	450	1.863	36%
	mam	126.197	51.805	450	2.442	71%
	rout	130.421	25.803	450	1.216	85%
	us	120.789	28.268	450	1.333	86%

Identical patient arrival figures were used for both models. Significant differences were noted for the total processing times for all five patient types as listed in Table VII;

Table VII

t-tests NBACH RAD p = .01		
patient	t	
ct	-27.5206	> 2.576
flu	-20.4844	> 2.576
mam	-19.2752	> 2.576
rout	-40.2527	> 2.576
us	-39.1786	> 2.576

As expected the workload for the physician in model #2 is almost

twice the workload of model #1;

Table VIII

Physician Usage - NBACH Radiology			
	# times used	average minutes / use	% utilization
MODEL 1			
doc1	45.78	7.39	48%
doc 2	30.78	7.43	33%
MODEL 2			
doc	76.57	7.29	82%

The utilization percentages for the models indicate time taken by each physician to interact with patients and staff, access the PACS system, and to conduct preliminary evaluations of images. Utilization percentages **do not** account for time spent conducting in depth image analysis, recording observations, attending meetings, and other administrative periods. Model #1 shows a realistic dichotomy between operational and administrative work which is approximately 50% for each. Model #2 shows the majority of the physician's time (> 80%) spent on operational issues while twice the work accumulates.

The results of this project suggest that patients will have to endure longer wait times. Longer wait times will come in the form of more days between appointment booking and appointment date. The impact to the radiology waiting rooms will be felt in the routine/US waiting room where a large portion of the

patients seen each day are urgent. The wait times for routine patients almost double from 70 minutes (in the two-physician model) to 130 minutes (for the one physician model). One avenue to lessen this impact would be the curtailment of scheduled appointments. An area for further study includes quantifying the increase in booking date to appointment date.

The radiology project is a fairly simple study, but it's seemingly obvious results may be a powerful tool for the BACH organization during a debate over personnel resources. One of the most challenging questions that medical leadership must struggle with as organizations are right sized and budgets decremented concerns maintaining access standards. Modeling can provide an arena for the evaluation of projects and policies but leadership must decide on the standards and the appropriate level to maintain.

Conclusion

Three different modeling projects have been discussed. Each project uses the simulation software and results in different ways to suit the problem under review.

The pharmacy project attempted to use modeling to evaluate the efficiency of three different pharmacy designs involving equipment placement and proposed construction. The pharmacy project highlighted the qualitative advantages of modeling. Quantitative results showed that wait times would be increased but this increase was deemed acceptable in the approved design.

The first question of the problem statement (p.7) *Can the use of simulation software help establish a better design for the BACH pharmacy?*, can be answered "yes". Modeling was just one piece of a larger "decision" puzzle in this project. The pharmacy project demonstrates how modeling can be folded into a composite briefing and used alongside other decision tools.

The laboratory project used simulation software to evaluate four different equipment placement designs in the NBACH. Each separate design was based on a specific process/function arrangement. The answer to the second question proposed in the problem statement, *Can the use of simulation software improve the operations of the Bassett Army Community Hospital (BACH) laboratory by optimizing the physical layout?* is yes. A design which emphasizes an equipment layout based on function and process was proven to provide more efficient processing of samples. The laboratory project demonstrates the value of simulation software in evaluating future projects and readying separate hospital sections for new settings.

The radiology project attempted to quantify the impact of proposed personnel resource decrements. The answer to the last question in the problem statement, *Can the use of simulation software quantify the impact of losing one radiologist at the BACH?*, is "yes". Simulation software can be an important tool for management in evaluating proposed personnel changes and may provide hard numbers to substantiate claims and support decisions.

The influence of modeling and simulation software will

continue to grow in all sectors of modern life. Man made systems which replicate systems in the "real" world are extremely valuable to managers, industry leaders, and scientists. Used for at least two decades in the industrial arena modeling is now making inroads in the service sector and is poised to bring health care organizations under its umbrella of enlightenment. From evaluating new safety features on automobiles, to providing virtual reality training for future surgeons, to modeling weather systems, and yes, testing the efficiency of hospital designs the uses of modeling are only limited by the ingenuity of it's users. Understanding the value which modeling can have to our organizations will only improve our ability to impact the present and influence the future.

Appendix I

Pharmacy BACH Data for Oct												
Arrivals - Downtown Patients												
	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800
5-Oct	0	0	1	8	1	0	6	2	6	2	1	0
19-Oct	0	3	5	2	5	4	1	3	0	5	0	0
26-Oct	0	4	3	4	5	1	3	5	3	2	0	0
6-Oct	0	4	9	6	4	3	1	1	4	0	1	0
13-Oct	0	3	3	7	0	0	6	8	3	0	0	0
20-Oct	0	4	1	6	5	0	2	6	1	3	0	0
27-Oct	0	0	7	7	4	8	2	15	15	2	0	0
7-Oct	0	3	1	0	11	8	4	0	7	7	0	0
14-Oct	0	0	2	2	12	7	3	5	6	10	0	0
21-Oct	0	2	1	4	3	5	5	6	11	2	0	0
28-Oct	0	0	1	3	3	3	14	2	8	2	0	0
8-Oct	0	0	0	1	1	1	7	10	4	9	0	0
15-Oct	0	0	0	0	0	0	5	2	9	8	0	0
22-Oct	0	0	0	0	0	0	9	9	14	9	0	0
29-Oct	0	0	0	0	0	0	13	8	2	3	0	0
9-Oct	0	0	1	9	13	4	7	8	9	7	0	0
16-Oct	0	3	0	3	1	1	3	2	0	2	0	0
23-Oct	0	5	4	1	6	0	6	2	3	2	0	0
30-Oct	0	2	3	8	0	2	7	5	6	3	0	0
min	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
max	**0**	**5**	**9**	**9**	**13**	**8**	**14**	**15**	**15**	**10**	**1**	**0**
mode	**0**	**0**	**1**	**0**	**0**	**0**	**6**	**2**	**6**	**2**	**0**	**0**
avg	**0**	**1.737**	**2.211**	**3.737**	**3.895**	**2.474**	**5.474**	**5.211**	**5.842**	**4.105**	**0.105**	**0**
std dev	**0**	**1.821**	**2.529**	**3.106**	**4.149**	**2.816**	**3.611**	**3.794**	**4.349**	**3.195**	**0.315**	**0**

Appendix I (continued)

Pharmacy BACH Data for Oct												
Arrivals - BACH Patients												
5-Oct	0	4	26	18	17	1	20	28	38	18	14	0
19-Oct	0	5	7	18	17	8	20	18	14	8	1	0
26-Oct	5	9	10	25	15	2	17	12	10	8	0	1
6-Oct	1	12	17	18	22	3	16	23	18	13	4	2
13-Oct	0	7	6	20	23	3	15	27	20	11	6	1
20-Oct	5	14	13	13	9	9	12	9	22	13	6	3
27-Oct	6	8	3	9	3	2	23	8	15	23	4	3
7-Oct	1	6		14	16	6	25	20	12	11	0	0
14-Oct	0	6	28	17	14	8	20	22	20	15	1	0
21-Oct	2	7	11	7	7	11	13	19	9	12	2	0
28-Oct	2	4	6	4	7	11	5	10	10	3	0	0
8-Oct	0	2	6	5	1	1	10	25	19	10	1	4
15-Oct	0	0	2	2	10	1	31	25	25	15	0	0
22-Oct	1	2	3	6	4	3	16	30	16	9	0	4
29-Oct	2	3	6	5	11	6	17	24	18	21	1	0
9-Oct	1	21	14	13	18	6	7	21	11	5	0	0
16-Oct	2	9	16	17	15	12	15	20	10	5	1	0
23-Oct	2	12	14	12	14	1	20	27	8	9	2	0
30-Oct	1	9	8	18	19	3	19	19	9	2	0	0
min	**0**	**0**	**2**	**2**	**1**	**1**	**5**	**8**	**8**	**2**	**0**	**0**
max	**6**	**21**	**28**	**25**	**23**	**12**	**31**	**30**	**38**	**23**	**14**	**4**
mode	**0**	**9**	**6**	**18**	**17**	**1**	**20**	**27**	**10**	**8**	**0**	**0**
avg	**1.632**	**7.3684**	**10.889**	**12.68**	**12.737**	**5.105**	**16.895**	**20.368**	**16**	**11.11**	**2.2632**	**0.9474**
std dev	**1.832**	**4.9689**	**7.4034**	**6.481**	**6.3144**	**3.77**	**6.1454**	**6.5592**	**7.3258**	**5.666**	**3.4616**	**1.471**

Appendix II

Decision Matrix			Pharmacy Remodeling				
weight		5.29	5.29	3.57	1.86	1.00	total
	criteria	supply workflow	waiting area mgmt	cost	privacy	wait times	
COA							
Option 1		1.5	1	3	1	3	28.809
Option 2		1.5	2.5	1.5	2	2	32.244
Option 3		3	2.5	1.5	3	1.5	41.539

Relative Values Matrix

Less is better

Consistency ratio = 96.40

Appendix III

t - tests (comparisons with current pharmacy) p = .05				
model	patient	t		
phar 1	BACH	-4.9001	> 1.96	
	downtown	1.6386	< 1.96	
phar 2	BACH	1.6070	< 1.96	
	downtown	4.0867	> 1.96	
phar 3	BACH	2.6007	> 1.96	
	downtown	5.5770	> 1.96	

Appendix IV

Laboratory Data										
	5th	8th	9th	10th	11th	12th	16th	17th	18th	19th
700		4	5	0	2	0	4	1	3	1
800		6	6	4	7	5	4	4	1	9
900		2	7	11	4	6	9	7	0	7
1000		19	6	3	2	2	8	5	3	2
1100		3	11	5	4	9	11	5	1	3
1200		2	0	2	3	1	11	3	0	3
1300		5	8	6	0	2	4	3	3	7
1400	3	3	5	4	1	6	7	3	5	3
1500	5	1	5	2	1	3	8	6	9	
1600	0	1	2	0	0	0	2	0	0	
1700										
	avg	std dev	min	mode	max					
700	2.2	1.7	0	4	5					
800	5.1	2.1	1	4	9					
900	5.9	3.2	0	7	11					
1000	5.6	5.1	2	2	19					
1100	5.8	3.5	1	3	11					
1200	2.8	3.1	0	3	11					
1300	4.2	2.4	0	3	8					
1400	4.0	1.7	1	3	7					
1500	4.4	2.8	1	5	9					
1600	0.6	0.8	0	0	2					

Appendix V

Laboratory Results - t - Test						
	t-test current model / model 1			p = .05		
urine	**2.36**	**>1.96**	**reject null hyothesis accept alternate**			
serum	**2.48**	"	**reject null hyothesis accept alternate**			
coagulent	**-1.66**	**< 1.96**				
	t-test current model / model 2					
urine	-2.54	> 1.96				
serum	-2.06	"				
coagulent	-2.62	"				
	t-test current model / model 2					
urine	2.17	> 1.96				
serum	2.84	> 1.96				
coagulent	0.50	< 1.96				

Appendix VI

BACH Radiology Data											
Arrivals											
mam											
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
22-Feb	0	1	1	1	1	0	1	0	1	0	0
23-Feb	0	1	0	1	1	0	1	1	1	0	0
24-Feb	0	1	1	1	1	0	1	0	0	1	0
26-Feb	0	0	1	1	1	0	1	1	1	0	0
min	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**
max	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**0**
mode	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**0**
avg	**0**	**0.75**	**0.75**	**1**	**1**	**0**	**1**	**0.5**	**0.75**	**0.25**	**0**
std dev	**0**	**0.5**	**0.5**	**0**	**0**	**0**	**0**	**0.577**	**0.5**	**0.5**	**0**
ct											
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
22-Feb	0	0	1	1	0	1	0	0	1	0	0
23-Feb	0	0	0	1	2	0	1	0	0	0	0
24-Feb	0	0	0	1	2	0	0	2	0	0	0
26-Feb	0	1	1	1	1	0	2	0	0	0	0
min	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
max	**0**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**1**	**0**	**0**
mode	**0**	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**
avg	**0**	**0.25**	**0.5**	**1**	**1.25**	**0.25**	**0.75**	**0.5**	**0.25**	**0**	**0**
std dev	**0**	**0.5**	**0.577**	**0**	**0.957**	**0.5**	**0.957**	**1**	**0.5**	**0**	**0**

Appendix VI (continued)

BACH Radiology Data													
Arrivals													
flu													
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**		
22-Feb	0	1	0	2	0	0	0	0	0	0	0		
23-Feb	0	1	0	1	0	0	0	0	0	0	0		
24-Feb	0	1	2	1	0	0	0	0	0	0	0		
26-Feb	0	1	1	1	1	0	0	0	0	0	0		
min	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
max	**0**	**1**	**2**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**		
mode	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
avg	**0**	**1**	**0.75**	**1.25**	**0.25**	**0**	**0**	**0**	**0**	**0**	**0**		
std dev	**0**	**0**	**0.957**	**0.5**	**0.5**	**0**	**0**	**0**	**0**	**0**	**0**		
rout													
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1800**
22-Feb	0	1	1	0	2	6	6	2	2	2	2	0	2
23-Feb	0	3	6	2	0	3	1	1	8	6	1	1	0
24-Feb	0	0	4	3	3	3	3	0	3	4	3	1	1
26-Feb	0	0	1	5	5	1	2	2	2	1	2	1	0
min	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**2**	**1**	**1**	**0**	**0**
max	**0**	**3**	**6**	**5**	**5**	**6**	**6**	**2**	**8**	**6**	**3**	**1**	**2**
mode	**0**	**0**	**1**	**#N/A**	**#N/A**	**3**	**#N/A**	**2**	**2**	**#N/A**	**2**	**1**	**0**
avg	**0**	**1**	**3**	**2.5**	**2.5**	**3.25**	**3**	**1.25**	**3.75**	**3.25**	**2**	**0.75**	**0.75**
std dev	**0**	**1.414**	**2.449**	**2.082**	**2.082**	**2.062**	**2.16**	**0.957**	**2.872**	**2.2174**	**0.816**	**0.5**	**0.9574**

Appendix VI (continued)

BACH Radiology Data											
Arrivals											
us											
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**
22-Feb	0	1	1	2	1	2	1	2	1	0	0
23-Feb	0	1	2	1	0	1	0	1	1	0	0
24-Feb	0	1	2	2	1	0	2	0	0	0	0
26-Feb	0	1	1	2	2	1	0	1	1	1	0
min	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
max	**0**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**0**
mode	**0**	**1**	**1**	**2**	**1**	**1**	**0**	**1**	**1**	**0**	**0**
avg	**0**	**1**	**1.5**	**1.75**	**1**	**1**	**0.75**	**1**	**0.75**	**0.25**	**0**
std dev	**0**	**0**	**0.577**	**0.5**	**0.816**	**0.816**	**0.957**	**0.816**	**0.5**	**0.5**	**0**

Appendix VII

Pharmacy Goodness of Fit Test - Patient Exits					
				alpha = .10	df = 1
	observed	**expected**	**chi value**	**chi squared statistic**	
BACH	133	118	1.9068	**2.015**	< 2.71
downtown	35	37	0.1081		

Radiology Goodness of Fit Test - Patient Exits					
				alpha = .10	df = 4
	observed	**expected**	**chi value**	**chi squared statistic**	
ct	4.75	6	0.2604	**1.020**	< 7.78
flu	3.25	4	0.1406		
mam	8.33	8	0.0136		
rout	25.6	22.044	0.5736		
us	8.5	8	0.0313		

Figure 1

Option 1 - BACH Pharmacy

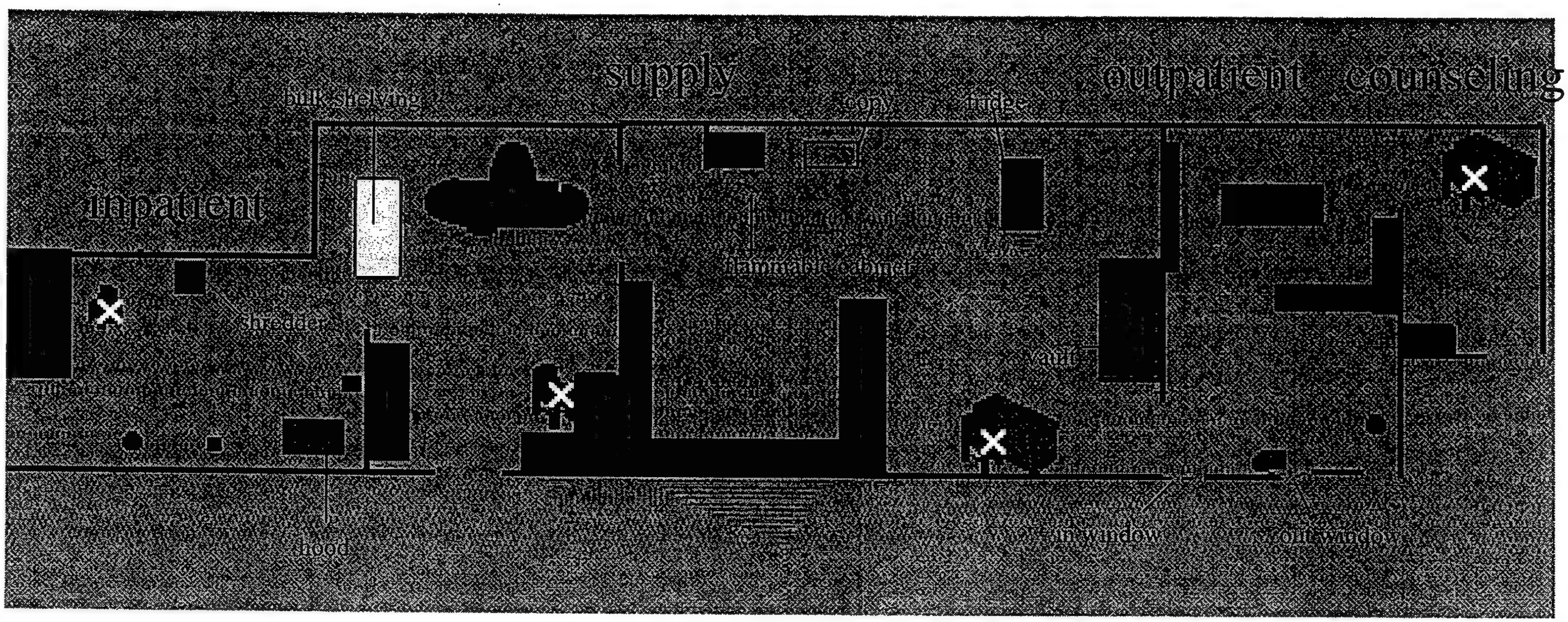


Figure 2

Option 2 - BACH Pharmacy

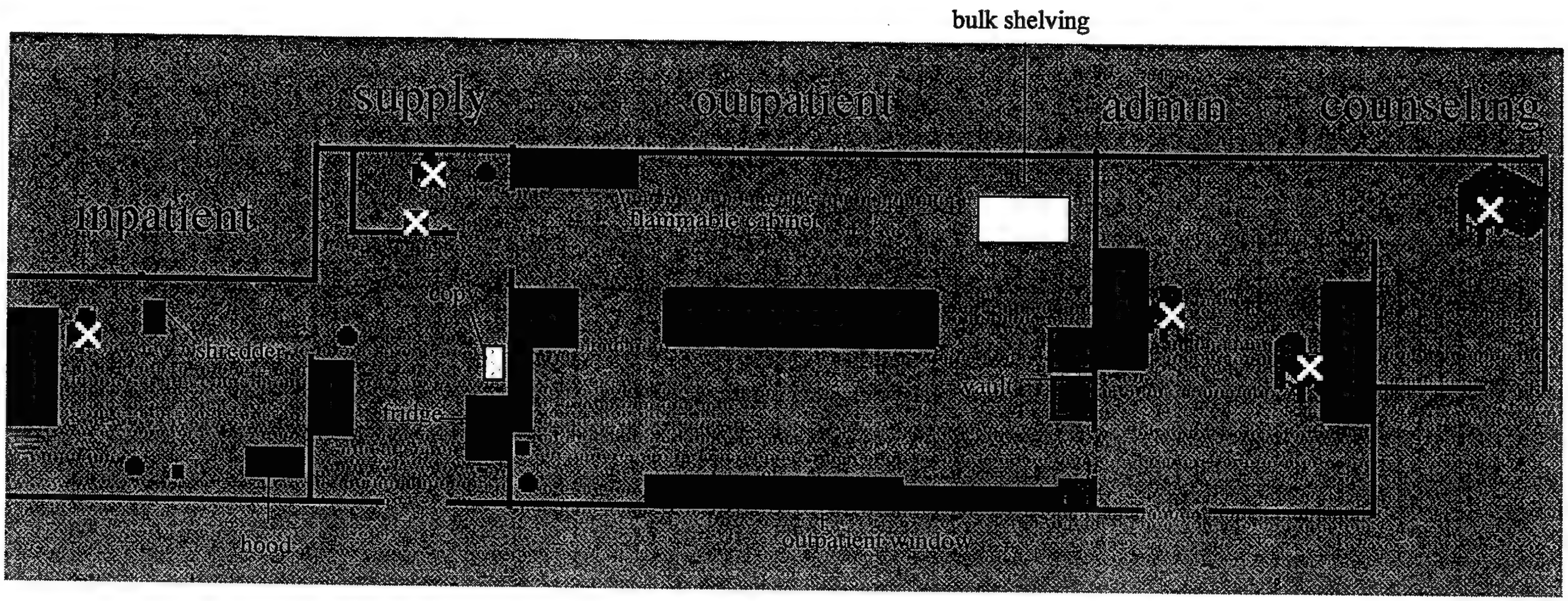


Figure 3

Option 3 - BACH Pharmacy

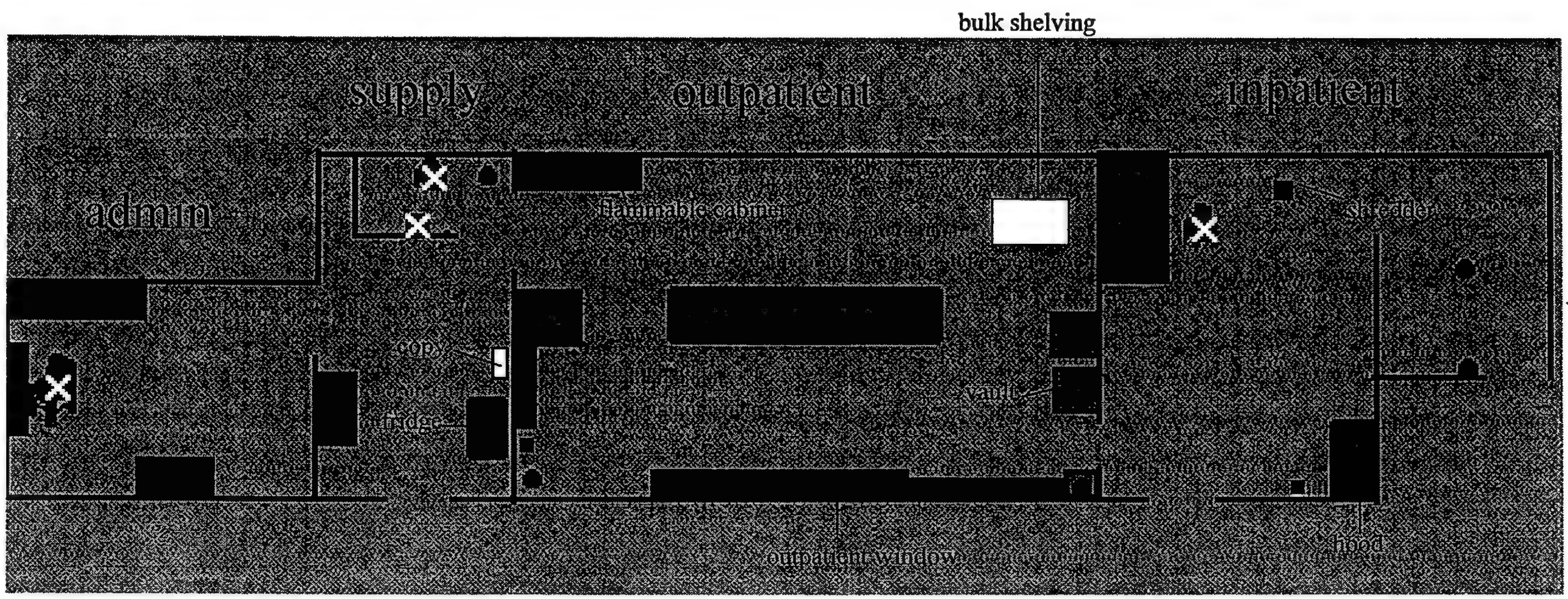


Figure 4

Current - BACH Pharmacy

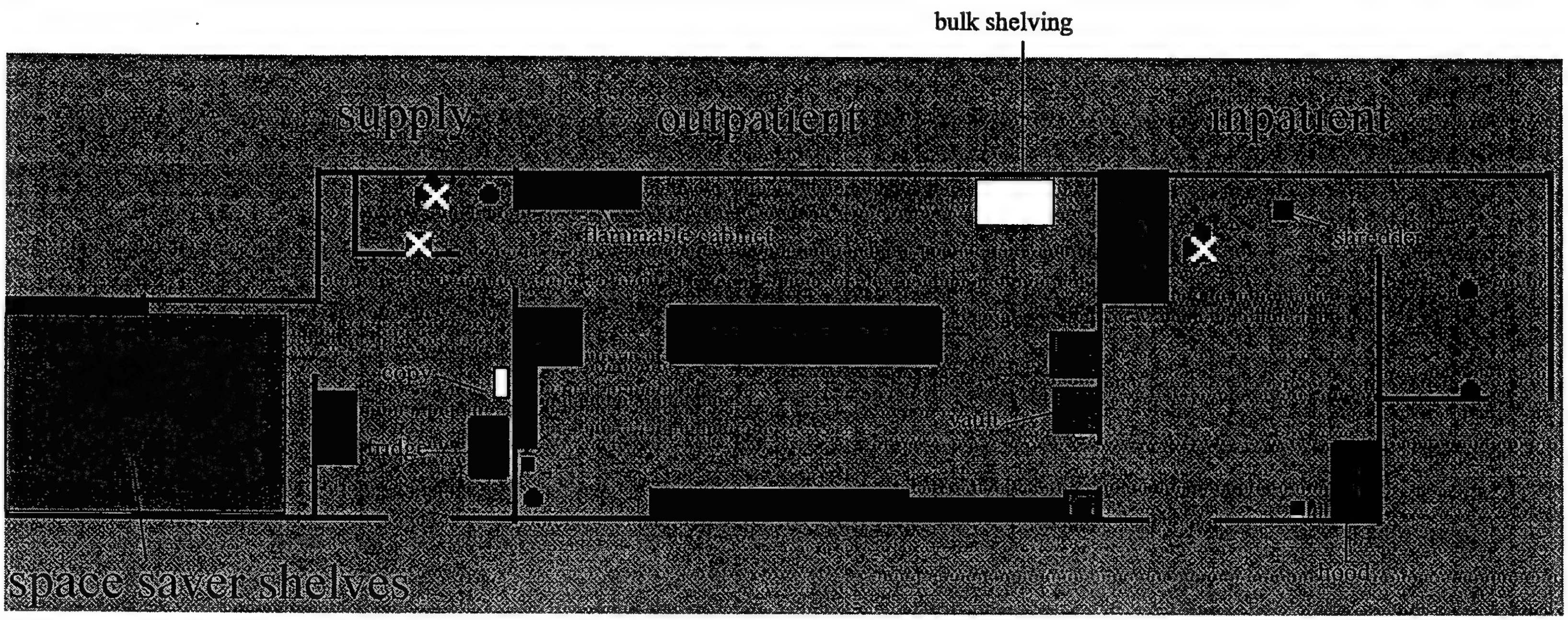


Figure 5

NBACH Laboratory MODEL # 2
arranged by FUNCTION

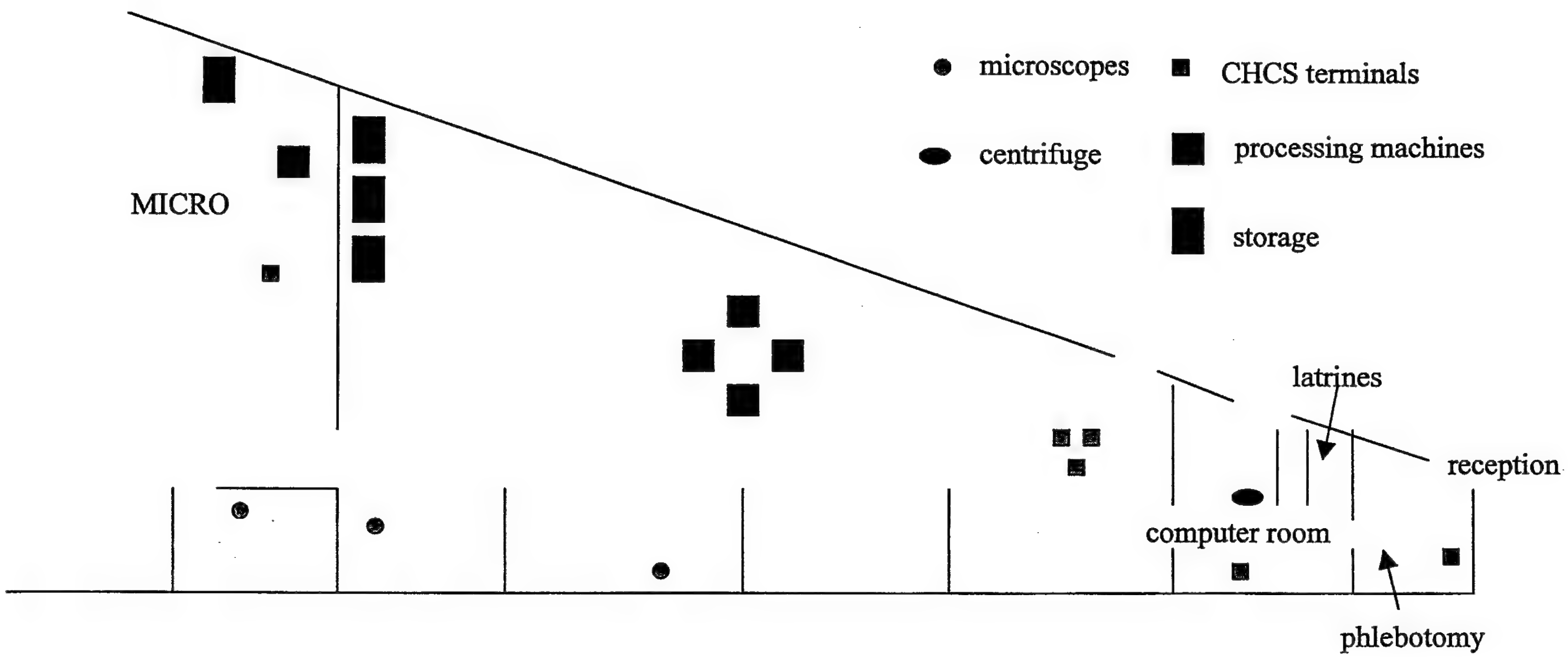


Figure 6

NBACH Laboratory - CURRENT MODEL
arranged by PROCESS

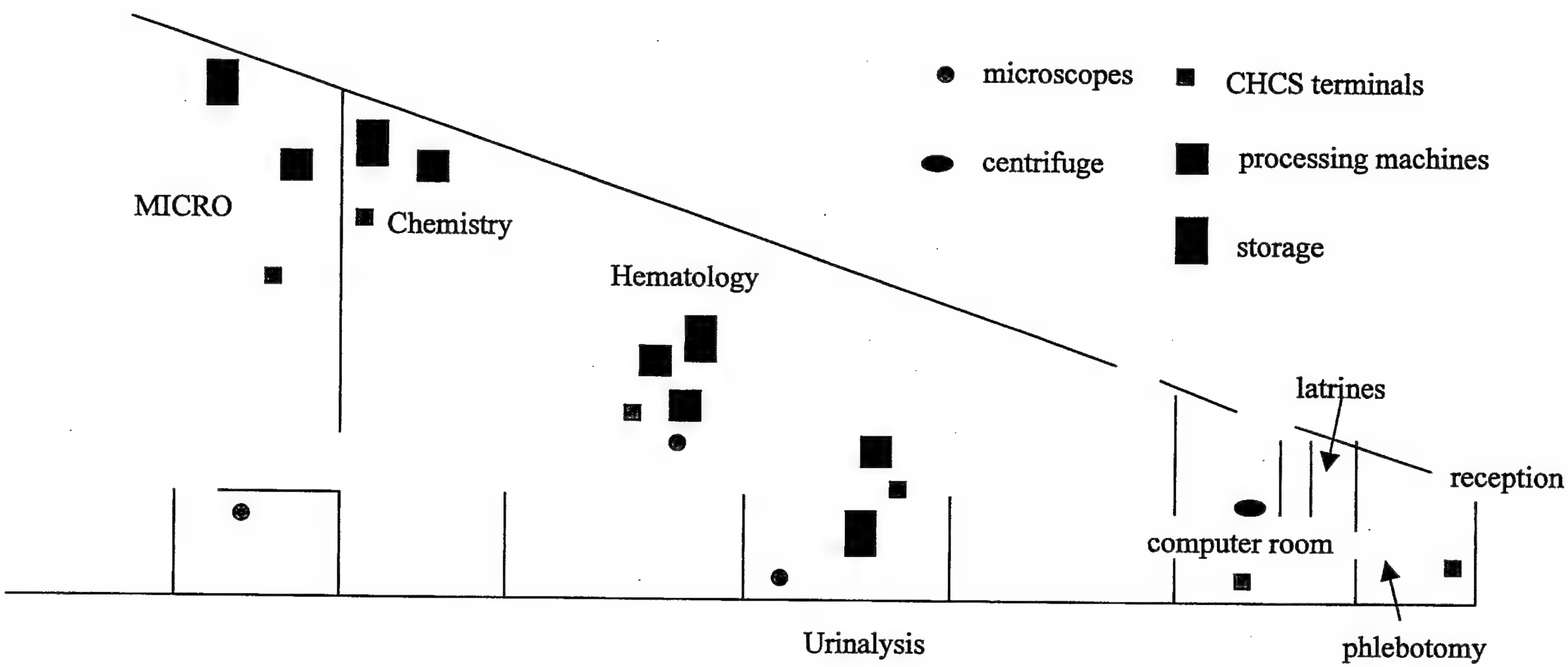


Figure 7

NBACH Laboratory - MODEL # 3

PROCESS - horizontal FUNCTION - vertical

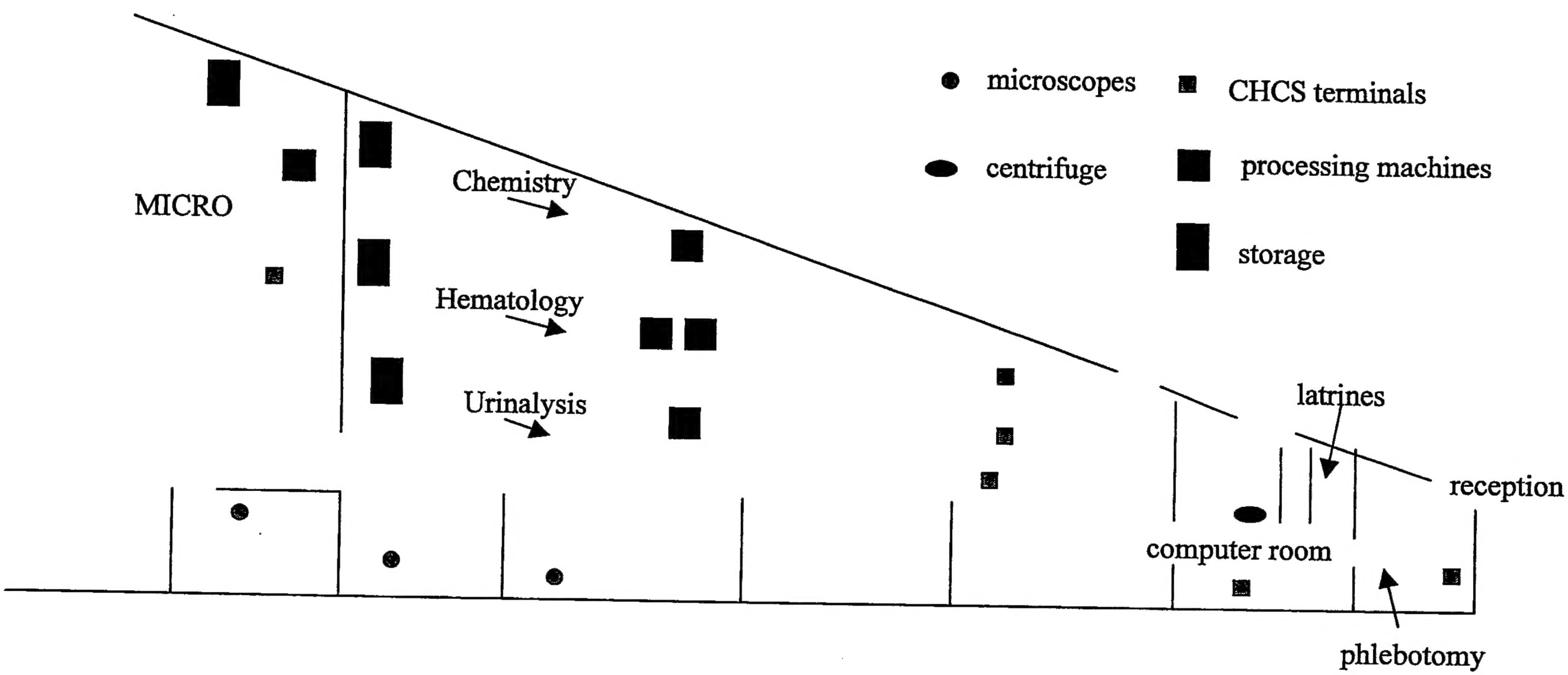
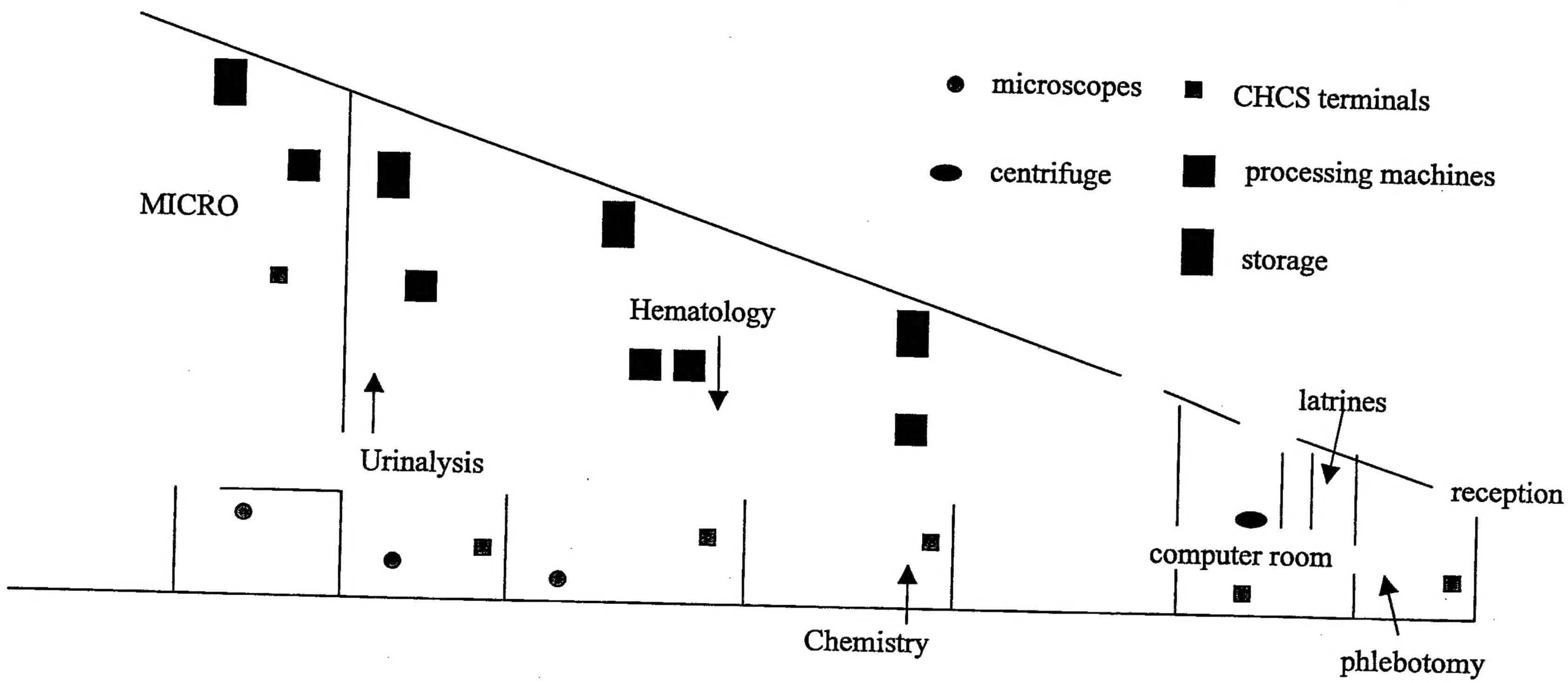


Figure 8

NBACH Laboratory - MODEL # 1
PROCESS - vertical FUNCTION - horizontal



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